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To cite this article: Philip Furley, Robert Schnuerch & Henning Gibbons (2016): The winner takes it all: Event-related brain potentials reveal enhanced motivated attention toward athletes' nonverbal signals of leading, Social Neuroscience, DOI: 10.1080/17470919.2016.1182586

To link to this article: http://dx.doi.org/10.1080/17470919.2016.1182586
The winner takes it all: Event-related brain potentials reveal enhanced motivated attention toward athletes’ nonverbal signals of leading

Philip Furley, Robert Schnuerch* and Henning Gibbons

ABSTRACT
Observers of sports can reliably estimate who is leading or trailing based on nonverbal cues. Most likely, this is due to an adaptive mechanism of detecting motivationally relevant signals such as high status, superiority, and dominance. We reasoned that the relevance of leading athletes should lead to a sustained attentional prioritization. To test this idea, we recorded electroencephalography while 45 participants saw brief stills of athletes and estimated whether they were leading or trailing. Based on these recordings, we assessed event-related potentials and focused on the late positive complex (LPC), a well-established signature of controlled attention to motivationally relevant visual stimuli. Confirming our expectation, we found that LPC amplitude was significantly enhanced for leading as compared to trailing athletes. Moreover, this modulation was significantly related to behavioral performance on the score-estimation task. The present data suggest that subtle cues related to athletic supremacy are reliably differentiated in the human brain, involving a strong attentional orienting toward leading athletes. This mechanism might be part of an adaptive cognitive strategy that guides human social behavior.

Recent research has demonstrated that perceivers rated leading athletes as more dominant, more proud, and more confident than trailing athletes without being aware of the score (Furley & Schweizer, 2016). All of these dimensions have been associated with high social status in the past (Driskell & Salas, 2005; Hall, Coats, & LeBeau, 2005; Mazur, 2005) and suggest that athletes change their nonverbal behavior along the verticality dimension when they are leading or trailing (Burgoon & Hoobler, 2002; Hall & Friedman, 1999). The vertical dimension of status in social relations stands in contrast to the horizontal dimension of emotional closeness (Burgoon & Hoobler, 2002; Hall & Friedman, 1999). In modern societies, sport competitions can be considered an institutionalized form of status contests (Laurens, Raymond, & Faurie, 2009; Lombardo, 2012; Mazur, 2005; Mehta, Jones, & Josephs, 2008). In these contests, sending cues such as dominance (Carney, Cuddy, & Yap, 2010; Carney, Hall, & Smith LeBeau, 2005), pride (Martens, Tracy, & Shariff, 2012), and confidence (Driskell & Salas, 2005; Mazur, 2005) serves the adaptive function of navigating the social hierarchy by letting other people know who deserves high or low status (Henrich & Gil-White, 2001).

ARTICLE HISTORY
Received 23 October 2015
Revised 21 March 2016
Published online 13 May 2016

KEYWORDS
Nonverbal behavior; ERPs; LPC; sport; status

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Of course, the evolutionary relevance of status displays implies that such cues are not only sent, but also reliably perceived and correctly identified. According to the ecological theory of person perception (McArthur & Baron, 1983; Zebrowitz & Collins, 1997), our cognitive system has become particularly attuned to perceptual cues that are of general adaptive relevance, such as status cues (see Anderson, Hildreth, & Howland, 2015; Schmid Mast & Hall, 2004). Efficient perception of status displays is most likely not limited to its utility for the survival of the species, but also serves adaptive functions at the level of individual goal attainment (McArthur & Baron, 1983; Zebrowitz & Collins, 1997). One of the most essential strategies should be a thorough representation of individuals that should be avoided in a confrontational situation (see Tracy & Robins, 2008; Tracy, Shariff, & Cheng, 2010). Hence, leading athletes, whom we perceive as dominant, proud, confident, and currently superior (Furley & Schweizer, 2016), should be of higher ecological importance than neutral or low-status displays (drawing athletes or trailing athletes, respectively).

Crucially, the importance of subtle nonverbal cues displayed by leading athletes should have a distinct effect on basic cognitive processes. It is well established that we orient our attention toward motivationally relevant stimuli (Ito, Larsen, Smith, & Cacioppo, 1998), which might allow a more thorough encoding and, thus, an enhanced mental representation of significant objects. An elegant way of monitoring the deployment of attentional resources toward different sensory events is via event-related brain potentials (ERPs), derived from continuous electroencephalographic (EEG) recordings. Specifically, the late and sustained attentional selection of motivationally relevant objects has been described and validated in various previous studies: The late positive complex (LPC; Sutton & Ruchkin, 1984), a broadly distributed positivity starting as early as 200–400 ms into stimulus processing and extending up to several seconds (Ito & Cacioppo, 2000), is a reliable indicator of attentional variations during the processing of motivationally relevant stimuli (Cacioppo, Crites, & Gardner, 1996; Hajcak & Olvet, 2008; Ito & Cacioppo, 2000; Ito et al., 1998; Olofsson, Nordin, Sequeira, & Polich, 2008). The neural source of the LPC consists of a network coding both sensory and affective features in cortical (e.g., ventrolateral prefrontal and cingulate cortex) and subcortical (e.g., amygdala) brain structures (Liu, Huang, McGinnis-Dewese, Keil, & Ding, 2012). Importantly, there is no simple correspondence between LPC amplitude and valence. Instead, it generally reflects the degree of motivated attention, that is, an orienting toward salient and relevant stimuli in a given context (e.g., Frühholz, Jellinghaus, & Herrmann, 2011; Gable & Harmon-Jones, 2010; Hajcak & Olvet, 2008; Kuhr, Schomberg, Gruber, & Quirin, 2013; Pastor et al., 2008; Schupp et al., 2000; Weinberg & Hajcak, 2011).

Based on previous research on our ability to monitor and interpret nonverbal behavior in sports (see, e.g., Furley & Schweizer, 2014, 2016) as well as on ecological theories of person perception (McArthur & Baron, 1983; Zebrowitz & Collins, 1997), we hypothesized that an LPC should be discernible while participants viewed brief stills of athletes and estimated the current score along the leading-trailing dimension (Furley & Schweizer, 2014). Crucially, the LPC should be more strongly pronounced for actually leading than trailing athletes, which would indicate a late, sustained attentional prioritization of these socially relevant individuals. We tested this idea in a straightforward ERP study.

Method
Participants
Forty-five healthy volunteers (M = 23.980 years, SD = 3.299; 25 women) participated in the experiment after having given written informed consent. They received monetary compensation (8 euros per hour) for their participation. The sample size was based on Furley and Schweizer (2014) and data collection was terminated after completing 45 participants. Forty-two participants (93%) were students, most of them enrolled at German universities, majoring in a total of 24 different subject areas. The largest number of students sharing the same major was four (four medical and law students, each); only one psychology major participated in the study. None of the participants were professional athletes, nor did the sample include any students majoring in sport science. All participants were blind as to the specific hypotheses of the study and were presented with the same standardized on-screen instructions. Thirty-seven participants (82%) reported being right-handed, while seven (16%) identified themselves as left-handed and one (2%) as ambidextrous. Crucially, all analyses reported below were repeated after excluding left-handed and ambidextrous participants, which yielded no significant changes to any of the behavioral and ERP results.

Stimuli and apparatus
Participants estimated the score of a total of 90 images (derived from Furley & Schweizer, 2014, 2016) of athletes that were acquired by extracting the median frame (to avoid selection bias) from each video in a set of brief clips of individual athletes from basketball, table tennis, and handball (see supplementary material for the stimuli used in the present study). We copied the image that appeared
exactly halfway through each clip and used it as a still as we wanted to present stationary images rather than clips. All images were selected on the basis of the same criteria used in similar previous investigations (Furley & Schweizer, 2014). They depicted athletes during breaks in their current game (e.g., time-outs and free throws in basketball, or breaks between points in table tennis). We did not include images containing any obvious nonverbal signals of victory (such as raising both fists above the head) or defeat (such as hiding the face behind the hands). This was done so as to avoid nonverbal cues that have been linked to the final outcome in sport and are therefore too informative for estimating the score (Furley & Schweizer, 2014; Tracy & Matsumoto, 2008).

All images were shown on a 23-inch FFT monitor with a resolution of 1920 × 1080 pixels. A third of the images showed athletes that were currently trailing, while a third depicted athletes during a draw, and the last third showed athletes that were leading while the picture was taken. Each category (trail, draw, lead) consisted of an equal number of images from each sport (basketball, table tennis, and handball). All images were converted to gray scale, cropped such that they showed only the athlete (upper part of the body and face), and rescaled to a size of 300 × 180 pixels. To ensure that the images from the different categories did not differ in regard to physical attributes (e.g., brightness, contrast, or spatial distribution), we measured various physical parameters of all images using the software ImageJ, provided by the United States National Institute of Health (Schneider, Rasband, & Eliceiri, 2012). Analysis confirmed that the images in the different categories were not significantly different regarding any relevant physical attribute.

**Procedure**

Participants were seated in an electrically shielded EEG chamber, gave written informed consent, and were then prepared for the EEG session. After all electrodes were properly prepared, participants read their instructions on-screen. They were informed that they would see brief grayscale images of athletes and were asked to estimate each athlete's score after the image. To do this, they used the scroll wheel of the mouse, thus moving a tick mark on an 11-step vertical scale that ranged from “trail” at the bottom, via “draw” in the middle, to “lead” on top. Participants clicked the left mouse button to enter their rating after having moved the tick mark to the desired location on the scale. As shown in Figure 1, each trial began with a fixation cross lasting for 800–1200 ms, after which the target image appeared for 500 ms, followed by a black blank screen for another 500 ms. Then the rating scale appeared, prompting participants to enter their estimate via the mouse wheel.

The experiment consisted of two main blocks: all 90 images were presented in randomized order, after which participants could take a short break. Subsequently, all images were presented again in a newly randomized order. This was done to achieve a higher number of trials, which is necessary to obtain clean and reliable measures of neural activity in the EEG. Thus, each participant performed a total of 180 trials, of which 60 contained images of lead, draw, and trail situations, respectively. After the experimental session, participants filled out a questionnaire comprising demographic questions.

**Behavioral data analysis**

When somewhat arbitrary rating scales, such as the score-estimate scale in the present study, are used, there is considerable variation regarding the use of the scale (Walker & Vul, 2014), with some participants spreading their judgments more widely than others, and some responding on a much higher overall level than others. This can be circumvented quite easily by normalizing each participant’s ratings before averaging or comparing across participants (see, e.g., Schnuerch,
Trautmann-Lengsfeld, Bertram, & Gibbons, 2014; Walker & Vul, 2014). To this end, the mean of all ratings given by a certain participant was subtracted from each individual rating given by this participant, and the resulting difference was divided by the standard deviation of all of this participant’s ratings. The resultant z-standardized ratings served as the main behavioral dependent variable in the present study.

EEG recording, preprocessing, and analysis

An EEG was recorded from 64 high-impedance ActiCap active scalp electrodes (Brain Products, Gilching, Germany) placed according to the international 10-10 system. During recording, all data were referenced to FCz and later re-referenced to the mean of mastoid electrodes TP9/10. Impedances were kept below 10 kΩ, sampling rate was 500 Hz, bandpass was 0.1–70 Hz. Eye movements were recorded online and calculated offline for eye-motion correction (Gratton, Coles, & Donchin, 1983). Data were filtered offline (0.1–15 Hz) and screened for artifacts (amplitudes exceeding ± 100 μV), by which less than 10% of all trials in each condition of each participant were rejected.

As the EEG has a relatively coarse spatial resolution, so that most ERP components are registered at various electrodes, we created spatial clusters of electrodes. A 3 × 3 grid was created with three levels of caudality (anterior, central, posterior) and three levels of laterality (left, medial, right). This resulted in the following electrode clusters: anterior left (AF7, AF3, F7, F5, F3), anterior medial (Fp1, Fp2, AFz, F1, Fz, F2), anterior right (AF8, AF4, F8, F6, F4); central left (FT9, FT7, FCS, FC3, T7, C5, C3), central medial (FC1, FCz, FC2, C1, C2, C2), central right (FT10, FT8, FC6, FC4, T8, C6, C4); posterior left (TP7, CP5, CP3, P7, P5, P3, PO7, PO3), posterior medial (CP1, CPz, CP2, P1, Pz, P2, POz, O1, Oz, O2), posterior right (TP8, CP6, CP4, P8, P6, P4, PO8, PO4). The two spatial factors caudality and laterality were included in all ERP analyses, so we were able to roughly pinpoint the location of possible effects.

Statistical analysis

Behavioral and ERP data were analyzed by means of repeated-measures analyses of variance (ANOVAs). Whenever a test of sphericity (Mauchly, 1940) indicated that variances were not homogenous, degrees of freedom were correct by means of the procedure proposed by Greenhouse and Geisser (1959). In these cases, the uncorrected degrees of freedom and the correction factor ε are reported. As a measure of effect size, we report generalized eta squared (η²G; Bakeman, 2005). Post hoc tests were corrected for multiple comparisons (Holm, 1979).

Results

Correlation of score estimates

Given that participants estimated the score of each image twice (once per half of the session), we were able to assess how strongly these two estimations were related. For each participant, we determined the correlation between first and second untransformed ratings of all images, and the resulting correlation coefficients were Fisher-z-transformed. As shown in Figure 2 (a), first and second ratings were correlated in all participants, with a mean Fisher-z-transformed correlation coefficient of 0.473 (SD = 0.187). This is well above zero (t(44) = 16.999, p < .001, d = 2.529), which means that ratings in the first and second half were indeed strongly related. This justifies the previously described averaging of first and second ratings to obtain a single dependent variable.

Effect of actual score on score estimates

Normalized rating estimates were submitted to a repeated-measures ANOVA with three-level factor Actual Score (trail vs. draw vs. lead). As shown in Figure 2(b), participants’ estimates varied strongly as a function of the score in the images, which is clearly indicated by a significant main effect of Actual Score [F(2, 88) = 21.171, p < .001, η²G = 0.070]. Post hoc pairwise comparisons revealed that score estimates were lower in the trail as compared to the draw (p < .001) and to the lead condition (p < .001). Estimates in the draw and lead conditions were not significantly different (p > .999). Given the strong linear trend of estimate by actual score [F(1, 44) = 25.403, p < .001, η²G = 0.070], we determined a task-performance index for each participant as the linear increase of score estimates by increasing actual score (i.e., the slope of the estimate increase across the three actual-score conditions).

As in previous investigations (Furley & Schweizer, 2014), there was an interaction of Actual Score and Sport [F(4, 176) = 8.266, p < .001, η²G = 0.063]. Participants’ estimates increased strongly with increasing actual score for table tennis and handball, as shown by large mean task-performance indices (table tennis: M = 0.196, SD = 0.352; handball: M = 0.252, SD = 0.419). For the basketball images, estimates increased only slightly with increasing actual score, as revealed by a small mean task-performance index (M = 0.035, SD = 0.378). As we were not interested in the
effect of a particular kind of sport, we averaged across sport conditions in all subsequent analyses. This also allowed us to maintain both (a) a certain variety regarding the material upon which the analyses were based and (b) a sufficient number of trials to be able to assess ERPs in a clean and reliable fashion.

**ERP results**

Visual inspection revealed the expected LPC, broadly distributed across the scalp (see Figure 3). As in similar previous studies, the LPC started around 400 ms into stimulus processing and lasted for the entire duration of the epoch, including the 500 ms after stimulus offset. Although a slight offset response reflecting an update of perceptual processing can be seen at posterior electrodes (see Figure 3: posterior clusters around 600 ms), the LPC is only temporarily shifted by this effect. The offset response is clearly not the cause of the LPC difference, which is observable well before the offset. This is in keeping with the idea that the LPC is robustly present both during stimulus presentation and after its offset (Hajcak, MacNamara, & Olvet, 2010; Hajcak & Olvet, 2008). Based on our visual inspection and on a similar previous investigation (Hajcak & Olvet, 2008), we scored LPC amplitude as the mean voltage between 400 and 1000 ms after stimulus onset. To analyze possible effects of the different image categories and roughly localize the effect, we submitted LPC amplitude values to a 3 × 3 × 3 repeated-measures ANOVA with factors Actual Score (trail vs. draw vs. lead), Caudality (anterior vs. central vs. posterior), and Laterality (left vs. medial vs. right).

The ANOVA yielded a strong main effect of Caudality \([F(2, 88) = 30.032, p < .001, \eta^2_g = 0.170, \varepsilon = 0.607]\), based on the fact that LPC amplitude was largest at posterior sensors (anterior: \(M = 2.075, SD = 3.407;\)
Moreover, a significant main effect of Laterality emerged \[F(2, 88) = 11.232, p < .001, \eta^2_G = 0.021, \epsilon = 0.849\], with LPC amplitude being largest at medial sites (left: \(M = 3.649, SD = 3.163\); medial: \(M = 4.373, SD = 3.885\); right: \(M = 3.301, SD = 3.043\)). Thus, the potential observed in the present study revealed the typical LPC topography (see, e.g., Kuhr et al., 2013; Weinberg & Hajcak, 2011).

Importantly, we found a significant main effect of Actual Score on LPC amplitude \([F(2, 88) = 5.372, p = .006, \eta^2_G = 0.007]\). This effect was further qualified by a significant Actual Score \(\times\) Laterality interaction \([F(4, 176) = 2.974, p = .021, \eta^2_G = 0.001]\), and a significant three-way interaction Actual Score \(\times\) Caudality \(\times\) Laterality \([F(2, 88) = 2.204, p = .047, \eta^2_G = 0.001, \epsilon = 0.708]\). To disentangle the interaction, we compared LPC amplitude for trail, draw, and lead images at all electrode clusters and corrected for multiple comparisons (Holm, 1979). Trail images did not elicit an LPC amplitude that was significantly different from draw images at any electrode cluster (all \(ps > .163\)). Likewise, amplitude differences between draw and lead images did not survive correction at any cluster (all \(ps > .884\)). However, lead images elicited a stronger LPC amplitude than trail images at the central right, posterior medial, and posterior right electrode cluster (all \(ps < .003\)). No reliable difference in LPC amplitude was found at any other cluster (all \(ps > .054\)).

To explore whether the observed LPC effects were in any way related to participants’ ability to infer the score from the nonverbal cues, we assessed the correlation between individual LPC modulations and estimation
performance. We assessed the LPC effect for each participant as the medial posterior amplitude difference between the two conditions that were reliably differentiated by the LPC (i.e., lead and trail images). Analogously, behavioral performance was measured as the score-estimation difference between lead and trail images. As neither of the two variables was normally distributed (Kolmogorov–Smirnov test: both ps < .001), we submitted the scores to a nonparametric rank correlation analysis (Spearman, 1904). Given our expectation that LPC should be positively related to behavioral performance, a one-sided analysis was performed. Confirming our expectation, we observed a significant positive correlation between LPC and the behavioral effect \( \rho(45) = 0.334, p = .015 \).

**Discussion**

The first notable finding of the present study was the replication of the effect reported by Furley and Schweizer (2014) that sport scores are readily inferred from simple nonverbal cues, which is not a trivial research step considering the increasing calls for replication in the psychological literature (Pashler & Wagenmakers, 2012; Simons, 2014; Yong, 2012). Participants in the present study were able to distinguish between leading and trailing athletes: The current score of a sports game was estimated to be more in favor of a briefly observed athlete when this athlete was truly in the lead than when the athlete was trailing when the picture was taken. In line with previous research, this finding suggests that humans are well equipped for interpreting nonverbal changes along the vertical dimension of social relations occurring with leading or trailing in sports competitions (Furley & Schweizer, 2016). This process is consistent with ecological approaches to person perception (McArthur & Baron, 1983; Zebrowitz & Collins, 1997). Specifically, nonverbal behavioral changes in sports competitions occur because signaling winning or losing during an agonistic encounter among group-living primates has evolved as an important means of communicating status and facilitating intergroup coordination within dominance hierarchies (de Waal, 2007).

We found that the scores of leading athletes and of those in a draw were estimated very similarly, which is in contrast to Furley and Schweizer (2014, 2016). The similarity of the ratings of leading and drawing athletes in the present study is in line with a study in which athletes were asked to form impressions of opponents displaying *dominant* and *neutral* nonverbal behaviors (Furley & Dicks, 2012). The ratings of the dominant and neutral opponents were highly similar and only differed significantly from opponents displaying submissive nonverbal behavior. The authors argued that acting in a neutral manner while performing in sports seems to be perceived as a sign of relaxedness, competence, and mastery of the situation (see Warner & Shields, 2007, for a similar argumentation). Hence, one may speculate that the stills of both drawing and leading athletes showed cues related to higher social status as compared to the trailing athletes. This might mainly be driven by a lack of differentiation (of drawing and leading) on the observer’s part (as claimed above), but it could likewise be the consequence of insufficient differences in the expression of being in a draw and being in the lead. That is, people who are currently in a draw might behave in a relaxed and confident way that is hard to distinguish from their behavior when they are in the lead.

The second, and more important, aspect of the present study was to investigate whether the processing of leading athletes is characterized by an increased LPC. As expected, we observed a robust main effect of the actual score in the observed images on LPC amplitude. The effect was carried by a larger amplitude for images of leading as compared to trailing athletes, which is in line with our hypothesis. Interestingly, the effect was found not only over medial centroparietal brain regions, but also at right-side sensors. This parallels previous studies reporting a slight right-lateralization of LPC modulations, especially when participants engaged in evaluative judgments (see, e.g., Cacioppo et al., 1996). Moreover, we observed an LPC effect beyond the duration of the image presentation, which is in keeping with a prior study demonstrating that the LPC extends up to several seconds after the offset of an image (Hajcak & Olvet, 2008). Notably, we found that LPC amplitude was a predictor of participants’ estimates of the current score: Individuals with a robust LPC-based differentiation of leading and trailing athletes were particularly good at recognizing whether the athlete was currently in the lead. This strongly suggests that the LPC modulation observed in the present study was not an artifact, but rather reflects a crucial neural operation that feeds into overt behavior.

Based on a remarkable body of prior evidence regarding the functional significance of the LPC (e.g., Cacioppo et al., 1996; De Cesarei, Codispoti, & Schupp, 2009; Frühholz et al., 2011; Gable & Harmon-Jones, 2010; Hajcak & Olvet, 2008; Ito & Cacioppo, 2000; Ito et al., 1998; Schacht & Sommer, 2009; Sutton & Ruchkin, 1984; Van Strien, De Sonneville, & Franken, 2010), we interpret these findings as support for our assumption that subtle differences in the display of nonverbal
signals entail a sustained attentional prioritization of visual information related to athletic supremacy. This notion is supported by recent findings that suggest that LPC-like enhancements reflect an attentional bias toward highly relevant information during social encounters (Bell et al., 2015; Schnuerch & Gibbons, 2015). Presumably, higher-order neural hubs that code affective information or govern the distribution of attentional resources provide top-down information that feeds, in a reentrant fashion, into structures coding basic perceptual features (see Liu et al., 2012). This way, the visual representation of motivationally relevant stimuli is enhanced.

Our findings and interpretation regarding the LPC are further supported by previous theorizing that the perception of athletes is based on capacities developed as part of an adaptive evolutionary profile (Furley & Schweizer, 2016). Detecting supremacy and high status allows the individual to abide by the rules of the social hierarchy and to avoid potentially harmful encounters. Our data indicate that the detection of subtle nonverbal signals that indicate high status in sports competitions (Furley & Schweizer, 2016) is accompanied by a thorough prioritization of a visual impression during late stages of processing. Remarkably, this attentional bias operates not only during actual encounters that are competitive and thus potentially harmful, but extends even to the sheer observation of images. Moreover, this bias appears to be stable and fundamental enough to operate even when we view sports scenes, which transmit conflict and fight only in the figurative sense.

Finally, some limitations of the present findings should be discussed. First, the behavioral results indicate that draw and lead images were perceived as similar, while trail images were rated as different from both of these categories. However, this pattern is not completely in accordance with the neurophysiological results as LPC amplitude differed only between lead and trail images. As the LPC sometimes indicates implicit differentiations beyond explicit ratings ((De Cesarei et al., 2009; Frühholz et al., 2011; Ito & Cacioppo, 2000; Schacht & Sommer, 2009; Van Strien et al., 2010), it is possible that the LPC represents the actual pattern of differentiation more reliably than overt responses. Clearly, this is speculative and needs to be tested in future studies. Second, the present study was clearly limited to the context of sports, although a more general mechanism might be at the heart of our findings (see also Furley & Schweizer, 2014). Indeed, we tentatively posit that this constitutes a fundamental aspect of social cognition in human interactions: High-status individuals should be detected and attended to with particular emphasis, so as to allow preparations of appropriate responses to this socially relevant individual. Future studies are needed to scrutinize this claim.

In conclusion, the present research highlights that people can distinguish between leading and trailing athletes based on briefly displayed images in which kinematic information is missing. The finding that sustained attentional processing differed between still images of leading and trailing athletes suggests that humans have evolved an efficient neural mechanism of orienting attention toward cues associated with high status and superiority, which should facilitate adaptive behavior amongst primates. As a side note, our data add to recent findings (Bell et al., 2015; Schnuerch & Gibbons, 2015) that highlight the role of the LPC as a solid indicator of essential selection processes in social cognition.

Acknowledgment

The authors thank Kristin Katschak, Hannah Kirsten, Jan Krawczyk, Charlotte Pensel, and Christina Wittinghofer for their assistance in data collection.

Disclosure statement

No potential conflict of interest was reported by the authors.

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